THE EFFECT OF TRACER PARTICLE SIZE ON FEED MIXING QUALITY

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Summary

Distribution of tracer particles in carrier conform to Poisson distribution and the effect of Poisson distribution on mixing uniformity can be reduced by increasing the tracer particle number per unit weight. In this paper, above-mentioned theory has been demonstrated by using three kinds of rotor whose pitches are different.

(Key Words: The Tracer Particle Number Per Unit Weight, The Poisson Distribution Effect)

Introduction

With the precise requirement for livestock raising and the thorough study of feed machines, it becomes important to research the effect of test conditions on mixing quality, as effect of Poisson distribution of tracer particle size can result in system error in mixing effect. In order to reflect the quality of the mixer correctly, it is necessary to further study the test conditions of mixing uniformity. As the test conditions vary with the feed requirement, the methyl violet is chosen only in this study of the Poisson distribution effect on mixing uniformity.

Materials and Methods

Corn meal

The corn meal ground by hammer mill with a 2 mm screen has been chosen. The corn meal specifications are as follows:

- The average particle diameter \( d = 0.33 \text{ mm} \)
- Particle homogeneity index \( s_g = 2.6 \)
- Bulk gravity \( r = 0.7 - 0.75 \text{ g/cm}^3 \)
- Content of moisture \( w = 13\% \)

Curves of particle-size distribution of the corn meal are shown in figure 1 and figure 2. The test has been done three times, so there are three curves in each figure and they changed into one curve eventually.

Tracer

The methyl violet is chosen as the test tracer. It is ground, sifted by screen with 120-, 150-, 200- and 320-mesh and then 0.5 g of sieved tracer is weighed for each test respectively. The following physical characteristics of the methyl violet are described.

a. Specific gravity is \( 1.3 \text{ g/cm}^3 \).
b. Particle-size distributions obey normal distribution and some specifications of the methyl violet particle are given in table 1.

The number of methyl violet particle and its average particle diameter should conform to the following relation:

\[ N = \frac{6G}{(\pi rd^3)} \]

Where

\( N \) = the number of methyl violet particle, grain

**TABLE 1. SPECIFICATIONS OF THE METHYL VIOLET PARTICLE**

<table>
<thead>
<tr>
<th>Mesh</th>
<th>Particle size range (( \mu \text{m} ))</th>
<th>Average diameter (( \mu \text{m} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>0–125</td>
<td>62.5</td>
</tr>
<tr>
<td>150</td>
<td>0–100</td>
<td>50</td>
</tr>
<tr>
<td>200</td>
<td>0–74</td>
<td>70</td>
</tr>
<tr>
<td>320</td>
<td>0–50</td>
<td>25</td>
</tr>
</tbody>
</table>

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Received July 14, 1988

Accepted December 22, 1988
Figure 1. Logarithmic normal distribution of the corn meal particle.

Figure 2. Cumulative particle-size distribution of the corn meal.

$G =$ methyl violet weight, g
$d =$ average particle diameter, mm
$r =$ specific gravity of methyl violet, g/cm$^3$

Figure 3 shows the relationship between theoretical content of methyl violet particles and their average diameters.

**Equipment**

The 9WJ50 mixer which can blend 50kg/batch corn meal is chosen as test prototype machine.
TABLE 2: SPECIFICATIONS OF THE MIXER (mm)

<table>
<thead>
<tr>
<th>Specification</th>
<th>330</th>
<th>440</th>
<th>660</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotator pitch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width of external ribbon</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Width of internal ribbon</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Length of internal adjusting ribbon</td>
<td>127</td>
<td>185</td>
<td>127</td>
</tr>
</tbody>
</table>

Note: The internal ribbon can be adjusted to any width by changing ribbon.

Procedures

Four kinds of methyl violet sieved by 120-, 150-, 200- and 320-mesh screen were used in testing three kinds of rotor, whose pitches are 330, 440 and 660 mm in case of material horizontal plane having been stable, adjusted by the internal adjusting ribbon. Materials which contained corn meal and each mesh methyl violet were blended 1, 2, 3, ..., 6 minutes with each kind of rotor respectively, then take 10 samples from every batch mixture, the sites where the samples were taken have been shown in figure 4 as A₁, A₂, A₃, ..., A₉, A₁₀.

Calculations.

The coefficient of variation is defined as

\[ cv = \frac{s}{m} \]

where

- \( s \) = standard deviation of the samples,
- \( m \) = mean value of the samples,
- \( n \) = number of the samples

\[ s = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - n \bar{x}^2}{n-1}} \]

\[ m = \frac{\sum_{i=1}^{n} x_i}{n} \]

\[ x_i = \text{value of the } i\text{'th sample} \]

The coefficient of variation can be calculated using the formula:

\[ cv = \frac{s}{m} \]

Hence the coefficient of variation for a Poisson distribution is:

\[ s^2 = m \]

if \( m \) is expressed with the number of tracer particles (N), then \( cv = 1/\sqrt{N} \) (figure 5).

According to the requirement for uniformity of formula feed and premixing feed, standard deviation and coefficient of variation due to the Poisson distribution of the tracer particle size should conform to the following relations.

\[ s \leq s^*, \quad cv \leq cv^* \]

where

- \( s \) = standard deviation of normal distribution of the sample
- \( s^* \) = theoretical standard deviation due to the Poisson distribution

Results and Discussion

It has been proved that the variation in particle sizes of the corn meal and the methyl violet belongs to normal distribution. For the different ingredients with the same particle-size distribution, the double-term distribution gradually changes into the Poisson distribution during mixing process.

One particular characteristic of the Poisson distribution is:

\[ s^2 = m \]

The ratio between \( cv \) for formula feed due to the Poisson distribution and the total \( cv \) is 3.01/10x100%, i.e. 30.1%. Likewise the proportion for
the premixing feed is 3.01/5×100%, i.e. 60.2%.

From above the error resulted from the Poisson distribution effect is quite considerable, particularly the coefficient of variation for the premixing feed cannot correctly reflect the mixing quality.

According to the method of equal precision, the effect of Poisson distribution on the premixing feed should be controlled within 1.5%, so the number of tracer particles in a 10 g sample should be:

\[ N = \frac{1}{cv^2} = \frac{1}{0.015^2} = 4,444. \]

On the basis of a proportion of the tracer added being 1/100,000 and the relationship between the average particle diameter and the content of the tracer particles in sample, the average particle diameter should be 0.032 mm.

In order to get a favourite uniformity of premixing feed, the sieve of 0.0634 mm opening should be used to sift the tracer particles.

Test results are shown in table 3 and figure 6.

From table 3 and figure 6 the mixing qualities of 330 mm- and 440 mm-pitch rotors are stabler and the values of cv are less than 10%, so the

**TABLE 3. MESH, PITCH AND COEFFICIENT OF VARIATION**

<table>
<thead>
<tr>
<th>Pitch (min)</th>
<th>Mesh</th>
<th>Value of cv (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>330</td>
<td>120</td>
<td>3.75±1.46</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>3.26±3.32</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>1.98±0.98</td>
</tr>
<tr>
<td>440</td>
<td>120</td>
<td>6.84±1.04</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>3.96±1.12</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>2.43±2.07</td>
</tr>
<tr>
<td>660</td>
<td>320</td>
<td>2.53±2.14</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>9.565±8.235</td>
</tr>
</tbody>
</table>

Note: "±" represents the maximum value of cv.

effect of Poisson distribution on mixing qualities of the two rotors is analysed only (table 4). Curves of their mixing uniformity are showed in figure 7 and figure 8.

From table 4, figure 7 and figure 8 the measured values of coefficient of variation vary with the number of methyl violet particles in case of other factors being constant. When using methyl violet particles through 200-mesh screen, the values of cv gained are not more than 5%. The more the number of methyl violet particle, the less the value
of cv, that is, the effect of Poisson distribution reduces with the increasing of the tracer particle number. Figure 9 shows the relationship between the tracer particle size and value of cv.

From the results of this work, the following conclusions can be drawn:

1. To improve the mixing quality, in addition to making a study of structure and parameters of the batch mixer, the effect of Poisson distribution on mixing uniformity should be considered. The Poisson distribution effect can be reduced by using more tracer particles in case of a certain additive proportion.

2. The tracer particle number varies with the requirements for feed, and the method of equal precision should be used to control the Poisson distribution effect.

Literatures Cited


